Surf Zone Mine Vulnerability

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Document #: N0001400WX20023
http://www.ih.navy.mil

LONG-TERM GOALS

The long-term goals of the mine vulnerability task are to: (1) identify key damage mechanisms leading to the development of kill criteria for explosive neutralization of a variety of anti-tank, and anti-personnel surf zone (SZ) threat mines, (2) develop and exercise a methodology for assessing the vulnerability of SZ mines to explosive mine neutralization, (3) assess the effectiveness of various types of mine neutralization systems against SZ mines, and (4) develop physics-based predictive capabilities for assessing system effectiveness against threat mines in a tactical SZ environment.

OBJECTIVES

The Navy is currently developing a number of explosive neutralization systems designed for large area SZ mine clearance. In support of these efforts, the objectives of this task are to:

- Characterize the vulnerability of SZ threat mines to explosive neutralization by establishing critical loading levels for neutralizing the mines
- Estimate the effectiveness of explosive neutralization systems in countering SZ threat mines
- Develop from this a general methodology.

APPROACH

The technical approach is to employ a combination of laboratory testing, analysis and simulation, and field testing to fully assess, for each threat mine studied, its vulnerabilities to explosive neutralization. The mines are studied through non-destructive physical analyses, static and dynamic function tests, material property tests, and ultimately exposure to dynamic explosive loading in a free-water, precision test environment. During dynamic loading studies, subject mines and fuzes are instrumented in order to time resolve the response of the target with the explosive event (i.e., shock, bubble, flow, etc.). The testing is supplemented by analyses in which advanced computer modeling simulates the interaction of both the mine target and the explosive system output, using a coupled Eulerian-Lagrangian hydrodynamic code. Laboratory and field-testing conducted during and following the analyses provide additional insight into kill/damage mechanisms and provides verification of the computer modeling predictions. Target response data, combined with explosive neutralization system lethality data in a simulated SZ environment, is being utilized to develop a non-deterministic predictive tool to assess DET and SABRE system performance in a SZ environment.

WORK COMPLETED

- Methodology was developed to assess the lethality of the DET array against target E mines considering the influence of multiple detonating cords in close proximity to the mines. This methodology was employed to update the effectiveness of DET against Target E. A technical report has been generated (see publication 1).
- The target E fuze safety pin jam has been successfully modeled (both analytically and using DYSMAS hydrocode) and explained (see publication 2).
- The vulnerability assessment of Target Q was initiated. The efforts include static target assessment, development of a finite-element structural model using the Dynamic System Mechanics Advanced Simulation (DYSMAS) Hydrocode, and phenomenology testing.
- A technical report on the explosive neutralization of Target E (see publication 3) has been published.
- A technical report on the explosive neutralization of Target L is in draft form.

RESULTS

Kill Probability of DET Against Target E

A comprehensive study of the effectiveness of DET against Target E, a surf zone mine, was completed in FY00. Initial effectiveness estimates for DET against Target E were based directly on the probability that DET would cover the target mine. A more accurate estimate of system effectiveness was desired. A general theory for estimating the effectiveness of a mine clearance system was developed which explicitly shows its dependence on test data and physical models of the mine's response. The effectiveness estimate is shown to be sensitive to the manner in which mine vulnerability information has been collected, i.e., to the experimental design. The fact that so many different types of tests involving DET and Target E have been conducted, in which numerous variables were controlled that would be random in the tactical scenario, was shown to so complicate the required effectiveness analysis that it was almost impossible to quantify the accuracy of the result. Nevertheless, a detailed analysis of the data was conducted from which it was possible to develop a crude and surprising effectiveness estimate. A safe, randomized method for conducting tests was suggested that would lead to more straightforward effectiveness estimates with quantifiable accuracy. The method would result in effectiveness estimates with much greater accuracy than can be achieved from the current vulnerability data and require far fewer mines.

Target E Fuze Safety Pin Jam

In 1998, SABRE line charge lethality tests were conducted at Weston-Super-Mare. The E mine was one of the targets evaluated. The results of the tests revealed a new response not seen previously in identical tests at the Eglin AFB Test Pond. In this new response, the safety pin is jammed into the fuze body and the mine is *potentially* neutralized. An analysis was made to investigate the probable cause of jamming. Based on the DYSMAS Hydrocode analysis and other analytics, it is hypothesized that the jamming was caused by the shock wave causing rotation of the tilt rod and simultaneously causing pressure inside the safety pin cap sufficient to drive the piston inside the copper tube, thus, causing the tilt rod to jam. However, it is believed that this is an unrealistic aspect of the test, in that the soluble link used to maintain the fuze in the safe position was removed prior to deploying the mine in the water. It is believed that jamming is not likely to occur in the tactical scenario where the soluble link is used. It is believed, however, that the mine will still be neutralized at similar standoffs due to the combined effects of high shock pressure and bubble flow causing sufficient rotation of the tilt rod to actuate the fuze. It is recommended that future tests be performed at the same site and conditions, and that the soluble link be used to confirm this hypothesis.

Target Q Vulnerability Assessment

A vulnerability assessment was initiated on two of the four fuzes associated with Target Q. All of the target Q fuzes are electronic. The effort focused on only two of the four fuzes for several reasons. One type of fuze was short in such supply, that is was unlikely that a useful vulnerability assessment could be conducted. The other fuze had acoustic functions that were not yet characterized. The acoustic characterization effort has recently begun at NSWCDL-CSS and is not yet complete.

For each remaining fuze type, a thorough mechanical characterization was performed. This characterization resulted in detailed component data (materials and dimensions), as well as component interaction, assembly and function information. In addition, a thorough electronic characterization was performed on both fuze types. The electronic characterization effort details the printed circuit boards, generates circuit diagrams and schematics, and leads to a thorough understanding of the electronic function of each of the fuzes. Together, the mechanical and electronic characterization efforts lead to a detailed understanding of fuze function in a tactical situation.

Hydrocode models were created and exercised in addition to the characterization efforts. A detailed DYSMAS finite-element model of Target Q was developed to determine stress and strain in the fuze components as well as estimating the velocity and acceleration of vital fuze components. Using the hydrocode models, shock loadings from an explosive charge detonated at various standoffs from the mine were computed. These loadings were compared with data from phenomenology tests that occurred in parallel to the modeling effort. Based on vulnerability analysis and tests of similar fuzes, focus was on the damage to fuze electronic components. The accelerations were computed at several locations in the general vicinity of the electronic components. Since it is impractical to compute the response of every circuit board and electronic component, shock-spectra analysis was used. For example, DYSMAS calculations provided accelerations at the circuit board supports. These accelerations were input in a shock-spectra computer program to compute acceleration, peak translational velocity and displacement as a function of the circuit board natural frequency. By estimating the range of natural frequencies of the circuit boards, peak translational velocities were calculated, which, in general, are insensitive to natural frequency over a wide range. The vulnerability of the electronic components was then assessed by comparing the estimated translational velocities to threshold values for kill from tests of similar electronic components. A sample shock spectrum plot can be seen in Figure 1.

The case of Target Q is fabricated from a plastic material. The cylindrical housing for the electronics is fabricated from an aluminum alloy. Knowing the strength of these materials, the shock levels to cause failure of structural components were estimated. For example, the phenomenology testing at SRI showed that, for a certain charge size, the top cover would rupture at a standoff of 24 inches. The DYSMAS analysis for this standoff and charge size also indicates very high strains, and in the fuze cover, a likely failure.

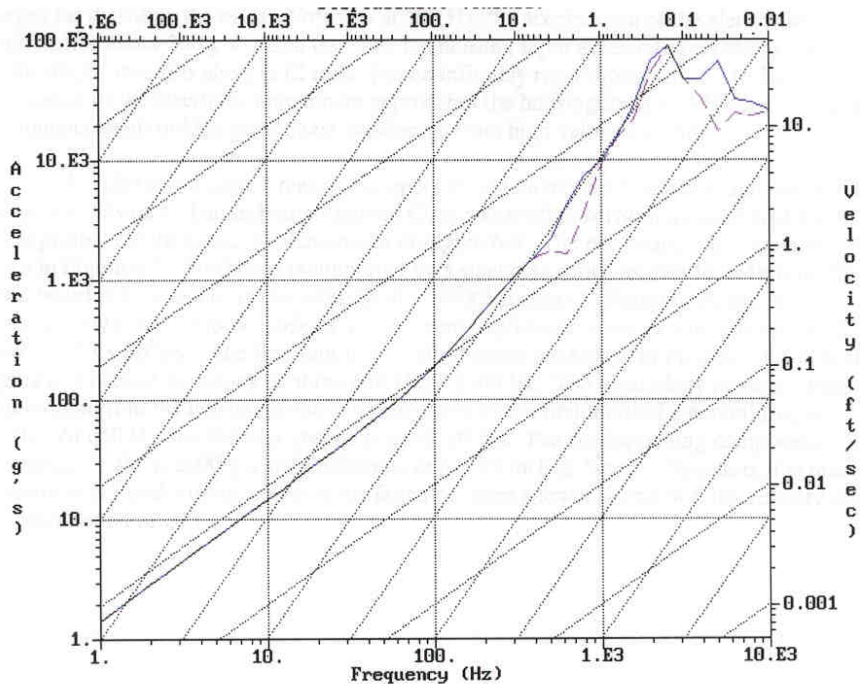

Figure 1. Sample Shock Spectrum Plot

IMPACT/APPLICATIONS

The technology developed provides invaluable data to the 6.4 community in assessing the vulnerability of threat mines and correspondingly, the lethality of explosive systems. For example, the methodology being developed to assess the lethality of the DET system against target E considering the effect of multiple detonating cords has resulted in a significant increase in the current predicted kill probability. Similarly, from previous years efforts in the mine vulnerability program, we know that peak pressure, impulse and energy flux developed by detonation of SABRE on a non-aerated bottom are much higher than similar detonations on an aerated sandy bottom. Hence the kill distances of the SABRE line charge may be significantly greater against certain mines than indicated by tests in the Eglin test pond.

The utility of the DYSMAS hydrocode in assessing the effectiveness of explosive systems against several threat mines in amphibious assault scenarios was once again demonstrated. We anticipate that this analysis tool will be improved, and allow us to make vulnerability assessments of future mine threats and ultimately reduce testing time and costs.

TRANSITIONS

The phenomenology test results, along with the analytic and hydrocode analyses have been, and will continue to be, employed to develop pre-test predictions, and aid in mine placement configurations for 6.4 system lethality tests. In addition, information and data on fuze damage mechanisms, and the associated threat status are provided to the 6.4 community to support lethality test efforts. As always, a copy of the 6.2 final report will be provided to the 6.4 community and MCM community at large to disseminate the valuable information regarding the new vulnerability data.

RELATED PROJECTS

PMS 407 is developing distributed explosives systems and is planning P3I programs for Surf Zone MCM.

ONR and the Naval Surface Warfare Center, Indian Head, MD are involved in an effort to quantify explosive phenomena in sand.

The joint U.S./German DYSMAS Project Agreement is providing a very powerful tool for use in assessing mine vulnerability.

PUBLICATIONS

McDonald, William W., 2000. Quantifying Mine Clearance System Effectiveness, A Case Study of DET Against A Surf Zone Mine, August, SECRET.

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